Title: Compensation methods for buried defects in extreme ultraviolet lithography masks

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Abstract

Two methods will be presented to compensate for buried defects in extreme ultraviolet (EUV) masks. The effectiveness of the compensation will be investigated with the simulator RADICAL [1] through focus for NA values expected for EUV insertion and beyond as well as off-axis illumination. The first method uses pre-calculated design graphs to determine the required absorber modification for a given defect. The second method attempts to engineer the spectrum transmitted by the absorber pattern to print the desired circuit pattern and to cancel out the spectrum reflected by the buried defect.

Buried defects are a major problem in EUV lithography because defects less than 1nm tall on the multilayer surface near absorber lines can cause greater than 10% CD change for 22nm dense lines [2]. For smaller lines, the allowable defect height will be even shorter. It may not be possible to reliably manufacturer EUV mask blanks without any defects larger than this limit so compensation could be necessary. Compensation for buried defects has been proposed previously and experimental wafer printing results show compensation should be possible [3]. The goal of the methods in this work is to prescribe modifications to the absorber pattern on the mask so that the final image printed on the wafer matches the intended pattern through focus.

The design graph method employs a simple two step algorithm: Determine the size of the critical dimension (CD) change due to the defect from an experimental aerial image of the mask or resist image and then use previous simulation data represented in a design graph to choose the size and shape of the modification to be made to the absorber near the defect.

The spectrum engineering method attempts to create an absorber pattern which will cancel out the spectrum from the defect while still printing the desired pattern. This is difficult because the ideal compensated absorber pattern often requires a transmission greater than one and phase-shifts not possible with standard absorber materials.

Changing the illumination and increasing the numerical aperture will have significant effects on the efficacy of the compensation. Increasing NA will improve image slope, but it will also affect the defect image. The smoothing processes applied to buried defects normally causes surface defects to be shorter and wider than the initial buried defect. Therefore, the mutual coherence of an off-axis illumination, like dipole, will cause the defect to interact with itself over many feature lengths, which means several edges must be monitored to determine if a compensation scheme is effective.

Abstract (50 Word)

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Supplemental Images

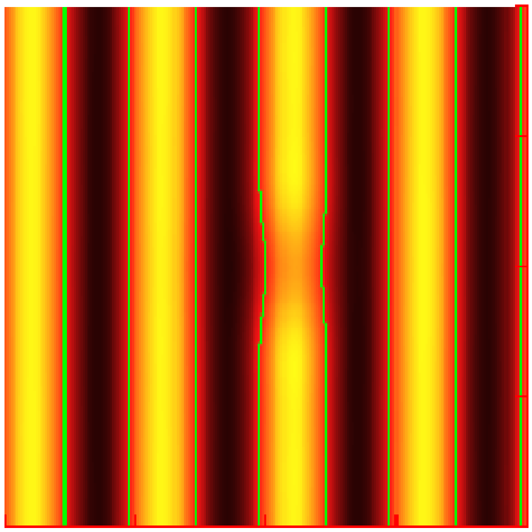

Figure 1. Aerial image resulting from 0.8nm tall 108nm FWHM defect (mask scale) near 22nm dense lines (wafer scale) at best focus. Space CD change = -15%.

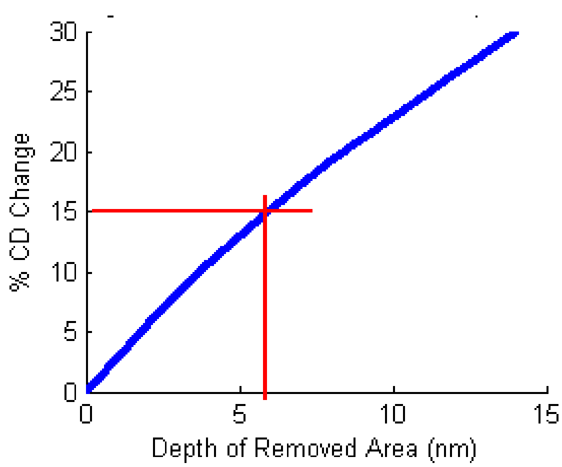

Figure 2. Design graph, which is a plot of %CD change as a function of removed depth for 110nm long bites, used to prescribe the removal of a section of absorber 110nm long and 6nm deep from the absorber line

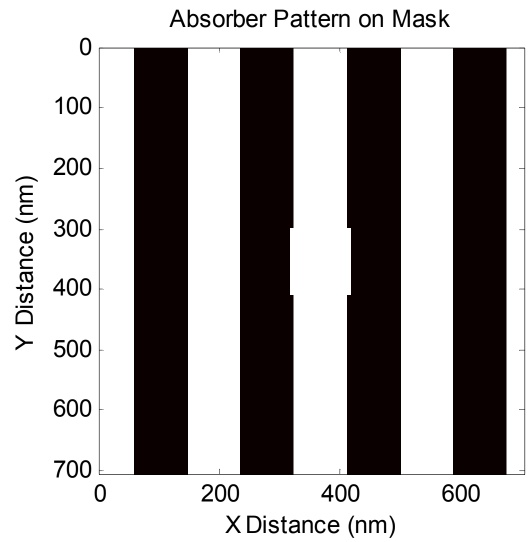

Figure 3. Compensated layout

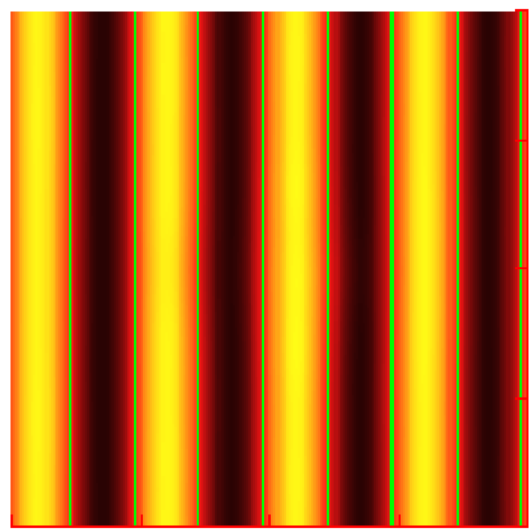

Figure 4. Compensated aerial image. CD Space CD Change = +3%

[1] C. H. Clifford, A. R. Neureuther, "Fast simulation methods and modeling for extreme ultraviolet masks with buried defects", J. Micro/Nanolith. MEMS MOEMS 8, 031402 (2009)

[2] C.H. Clifford, et al., "Comparison of fast three-dimensional simulation and actinic inspection for extreme ultraviolet masks with buried defects and absorber features," J. Vac. Sci. Technol. B 27, 2888 (2009)

[3] T. Liang, "Multilayer Defect Compensation to Enable Quality Masks for EUVL Production," presented at 2008 Int. SEMATECH EUVL Symp., Lake Tahoe (29 Sep. 2008).